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NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 243

PROPULSION SHAFTING

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CHAPTER 243

PROPULSION SHAFTING

243-1.1 GENERAL

243-1.1.1 PRIMARY PURPOSE. The primary purpose of propulsion shafting is to transfer the torque generated by the main engine to the propeller and to transmit the thrust developed by the propeller to the thrust bearing in the ship.

243-1.1.2 SYSTEMS DESCRIPTION. Sections of shafting outside the skin of the ship are supported usually by bearings located in struts, skegs. and stern tubes. Inside the skin of the ship, shafting is supported on line shaft spring bearings. To prevent water from flooding the ship through the areas where the shafting pierces the hull, there is installed a sealing system. Newer ships are usually equipped with the following sealing systems:

a. For surface ships. A split inflatable seal is installed aft of a stuffing box and gland which is designed for the alternate use of the split face-type seals or conventional packing.

b. For submarines. A split inflatable seal is installed aft of a single or tandem prime split seal assembly and, forward of the prime seal unit, a stuffing box, packing, and a gland is installed to serve as a standby seal in the event of failure of the prime seal.

The above inflatable seals are for use only when repairing or replacing the prime split seals with the ship waterborne and the shaft at rest.

243-1.1.3 CONSTRUCTION. Propulsion shafting for ships in naval service is usually forged in sections from alloy steel ingots and is generally hollow bored from end to end in combatant ships in order to accomplish a saving in weight. The after sections of the shafting are exposed to seawater. As a consequence, this shafting, which is inaccessible except when the ship is drydocked, must be protected from seawater corrosion (pitting) in order to avoid failure from corrosion fatigue. These after sections of shafting are protected by rubber or plastic covering applied over the exposed areas of the steel shafts.

243-1.1.4 DRYDOCK INSPECTION AND REPAIR. Waterborne shafting inspection and repair shall be accomplished at each drydocking as follows:

a. In-place inspection and repair is intended for those sections of waterborne shafting installed in the ship and accessible for inspection and repair.

b. In-shop inspection and repair is intended for those sections of waterborne shafting not accessible for in-place inspection and repair. Unless specified otherwise, the requirements contained herein are minimum requirements for the in-shop inspection and repair of shafting. Additional inspection and repair guidance is contained in the applicable Maintenance Requirement Procedure (MRP) or Technical Repair Standard (TRS) for shafting and may be used, wholly or in part, as substitution for the minimum requirements herein. Also note that ready-for-issue shafts are available from the Navy supply system for use if necessary.

c. Except on nuclear submarines, waterborne shafting enclosed in seawater bossings, stern tube, or skegs, and not accessible for in-place inspection and repair, shall be unshipped at intervals not to exceed 10 years or every other overhaul, whichever is less, for ships in service.

NOTE

Stern tube shafting may be accessible for in-place inspection. In-place inspection of stern tube shafting can result in significant cost avoidance and shall be considered prior to shafting removal. Inspections shall be in accordance with paragraph 243-1.1.7.1. In-place inspection of stern tube shafting has been documented on CG-47 class ships. Review of clearance data for other ships indicates that CVN-68, LHA-1, DD-963, DDG-993, DDG-51, and AOE-1 Classes are all potential candidates for in-place inspection. Entry to the stern tube can be accomplished through the forward end opening, aft end opening and/or accesses made specifically for this purpose. If inspected in place, these shafts may be reinspected at each drydocking to accessible shaft requirements or unshipped for reinspection at an interval not to exceed ten years from the last unshipping. However, special consideration for this in-place inspection is required for stern tube shafts installed at new construction on DD-963, DDG-993, CG-47, DDG-51, and LHD-1 Classes. Due to a difficult-to-inspect shaft covering unbonding problem associated with shafts provided for these hulls at new construction, it must first be determined that these shafts have been previously unshipped and recovered prior to implementing the in-place inspection option.

d. Waterborne shafting on nuclear submarines shall be unshipped and replaced with a ready-for-issue shaft from stock at each regular overhaul not to exceed 6-year intervals except in special cases as approved by the Naval Sea Systems Command (NAVSEA). Where replacement shafts are not available, the shaft shall be inspected and repaired within the overhaul period in accordance with the applicable Maintenance Requirement Procedure (MRP) or Technical Repair Standard (TRS).

243-1.1.4.1 When submarine shafts are removed, all shaft sleeves shall be dye penetrant checked in accordance with MIL-STD-271E, Section 5, Group I, (Non-Destructive Testing Requirements for Metals). Particular attention shall be paid to lock ring grooves and O-ring grooves, where applicable. If cracks are detected, details of location, size and depth as found by grinding and reinspection are to be reported to NAVSEA (Code 03Z41) for information.

243-1.1.4.2 In those cases where the removed shaft is to be repaired and reinstalled, the above dye penetrant inspection should be accomplished after new sleeves have been installed and final machining has been completed. In these cases, cracks detected shall be reported, including a recommendation for repair, to NAVSEA (Code 03Z41) for review and approval.

243-1.1.5 VIBRATION. When propellers are unshipped due to a possible propulsion shafting or propeller related vibration problem, measure the shaft taper runout for Fixed Pitch Propeller (FPP) shafting or the aft facial runout of the after-most shaft flange for Controllable Pitch Propeller (CPP) shafting. The following criteria shall be utilized to determine acceptable runout:

FPP Shafting. Determine the average shaft taper runout by averaging the maximum total indicator runout (TIR) values at each end of the taper. The average determined shall not exceed the lesser of the following values:

$$\text{Total Indicator Runout (TIR) (in inches)} = \frac{704.7}{(RPM)^2}$$

$$or\ TIR = 0.016\ inch$$

$$\text{Total Indicator Runout (TIR) (in inches)} = \frac{353.4}{(RPM)^2}$$

$$or\ TIR = 0.008\ inch$$

RPM = full power shaft revolutions per minute.

CPP shafting. Measure flange aft facial runout as close as practical to the outside diameter of the flange. The maximum runout shall not exceed the lesser of the following values:

Total Indicator Runout (TIR) (in inches) =(353.4) / $(RPM)^2$

RPM = full power shaft revolutions per minute.

NOTE

When turning shafting system for runout checks, ensure that all shaft bearings and other propulsion equipment are properly lubricated.

If the runout exceeds the above limits and cannot be readily straightened in place, unship the shaft for in-shop inspection and repair straightening.

243-1.1.6 BENT SHAFTING. Severely bent shafting shall be straightened in accordance with the requirements of MIL-STD-2191.

243-1.1.7 RUBBER AND PLASTIC COVERED SHAFTS.

243-1.1.7.1 In-Place Inspection. Conduct, at close range, a careful visual inspection of the full length of all accessible rubber and/or reinforced plastic covering for evidence of deterioration, physical damage, lack of adhesion, or other defects. Evidence of loss of adhesion of shaft covering is characterized by one or more of the following:

a. Loss of covering wholly or in part.

b. Rust stains where seawater has leaked through the covering in the vicinity of a cut, joint, patch, or other flaw.

c. For rubber covering. Look for water blisters which are typified by swells which are rather soft to the touch.

d. For plastic covering. Evidence of loss of adhesion is less easily detected with plastic than rubber. However, detecting the lack of bond of plastic covering has been successful by tapping the covering at regular intervals of about 18 inches along the length of the covering with a light hammer rap while holding the palm of one hand against the covering on the other side of the shaft. Discernible vibration, movement of the covering, or audible hollow sound is evidence of probable loose bond and should be explored or further examined.

Both rubber and plastic covering shall be inspected using a high frequency spark tester per MIL-STD-2199 for the detection of pinholes, porosity, or grit blast damage. Plastic covering is vulnerable to the grit blast cleaning processes employed to clean the hull; whereas, grit blast has little effect on rubber covering.

Particular attention must be given to the detection of breaks in the covering or leakage in the joint where the covering joins or laps on the shaft sleeve. Sleeve ends are the most vulnerable areas of the waterborne shafting. The shaft at the forward end, as well as the after end of the aftermost bearing sleeve, are the locations of nearly all propulsion shaft failures. Therefore, special attention must be given to the detection of breaks in the covering or leakage in the joint in these critical areas. However, shafts do fail at locations other than in the vicinity of the aftermost bearing. Failures within the stern tube are almost as frequent as those in the tail shaft, particularly on destroyer-type ships.

Where evidence is found of deterioration, physical damage, lack of adhesion, seawater penetration at the joint at ends of sleeves or other defects, remove the covering for a distance of at least 10 inches beyond the maximum extent of seawater penetration. If seawater is present or has deteriorated the sleeve to covering interface at the end of the sleeve, the sleeve end shall be machined or chipped back 1/4 inch beyond the farthest point of penetration or contact with seawater on the shaft surface. The repair activity shall use sound judgment in determining the length of each sleeve cut prior to reaching this farthest point of seawater contact on the shaft. Shorter cuts (1/4 inch or less) can add unnecessary time and expense while increasing the risk of accidental cuts into the shaft surface. On the other hand, longer cuts (1 inch or more) can remove more sleeve length than is necessary, leading to a greater possibility of premature sleeve replacement, a costly repair which requires shaft removal to the shop. To assist in the assessment of sleeve cut lengths, the repair activity shall determine the available excess sleeve length utilizing the applicable shaft, bearing and fairwater drawings coupled with actual sleeve length measurements. A sleeve end that has been chipped back for inspection shall be remachined in accordance with the shaft detail drawing to accept new shaft covering. All exposed areas of the shaft, including propeller shaft tapers and keys, shall be inspected by the magnetic particle or dye penetrant method in accordance with MIL-STD-271. All cracks shall be explored to their full depth and removed by grinding.

NOTE

Whenever a magnetic particle inspection is accomplished, the shaft shall be demagnetized to 7.0 gauss maximum.

243-1.1.7.2 In-Shop Inspection. Particular attention must be given to the detection of breaks in the covering or leakage in the joint where the covering joins or laps on the shaft sleeve. Note all locations where seawater is present or has deteriorated the joint at the end of the sleeve. Remove all rubber or plastic covering from the shaft. If seawater is present or has deteriorated the sleeve-to-covering interface at the end of the sleeve, the sleeve end shall be machined or chipped back 1/4 inch beyond the farthest point of penetration or contact with seawater on the shaft surface. The repair activity shall use sound judgment in determining the length of each sleeve cut prior to reaching this farthest point of seawater contact on the shaft. Shorter cuts (1/4 inch or less) can add unnecessary time and expense while increasing the risk of accidental cuts into the shaft surface. On the other hand, longer cuts (1 inch or more) can remove more sleeve length than is necessary, leading to a greater possibility of premature sleeve replacement. To assist in the assessment of sleeve cut lengths, the repair activity shall determine the available excess sleeve length utilizing the applicable shaft, bearing and fairwater drawings coupled with actual sleeve length measurements. When machining or chipping back the end of the sleeve would result in the ineffectiveness of the sleeve, the sleeve shall be replaced; for example, in way of bearings and coupling covers. After removing covering and/or sleeves, all exposed areas of the shaft, including propeller shaft tapers and keys shall be inspected by the magnetic particle or dye penetrant method in accordance with MIL-STD-271. All cracks shall be explored to their full depth and removed by grinding.

243-1.1.7.3 Rubber or Plastic Covering Repair and Replacement. Rubber or plastic covering removed for inspection of the shaft surface shall be replaced after repairs to the shaft have been completed.

a In-Place Repair. For rubber covered shafts, replace the covering removed with Type II of MIL-R-15058. The use of brush-on rubber Type IV is forbidden except on coupling flanges and bolts where flange couplings are not protected by watertight metal coupling covers. For plastic covered shafts, replace the covering removed in accordance with MIL-STD-2199. Use of plastic resin alone is forbidden except on coupling flanges and bolts where flange couplings are not protected by watertight metal coupling covers. All surfaces of flange couplings, including bolts and nuts, which are not protected from seawater by metal, watertight, rotating coupling covers, except for the aftermost flange coupling for controllable pitch propellers, shall be covered with brush-on Type IV of MIL-R-15058 for rubber covered shafts or in accordance with MIL-STD-2199 for plastic covered shafts.

NOTE

Rubber, once an optional material for shaft covering, is no longer being used to protect shafts, and MIL-R-15058 has been canceled. However, since older ships may still have shafts with rubber covering, minor covering repairs to these shafts may still be accomplished by use of the following acceptable commercial substitute if MIL-R-15058 material cannot be located:

For MIL-R-15058, Type II, use GACO N-3S Cold Bond Sheet Stock and GACO N-29 Black Cold Bond Air Curing Neoprene Bonding Agent.

For MIL-R-15058, Type IV, use GACO N-250 Neoprene Troweling Compound.

These GACO products are available from:

Gates Engineering Co. Inc.
100 South West Street
Wilmington, Delaware 19801

If extensive rubber covering repairs to these shafts are required, consideration should be given to complete removal of the existing rubber covering and replacement with plastic covering in accordance with MIL-STD-2199.

b. In-Shop Repair. For rubber or plastic covered shafts, replace the covering with plastic in accordance with MIL-STD-2199.

243-1.1.8 ECCENTRICITY. Shafting unshipped for in-shop inspection and repair shall be checked for eccentricity (runout) in accordance with the procedures and criteria of the applicable MRP or TRS.

243-1.1.9 CRACKS AND PITTING IN SHAFTING.

243-1.1.9.1 For Shaft Surfaces. Complete removal of all cracks found is mandatory. Crack removal shall be confirmed in each instance by the magnetic particle or dye penetrant method. Cracks and/or pits exceeding the following criteria shall be repaired by welding in accordance with MIL-STD-2191.

a. Minor pitting, but no cracks, detected not exceeding 1/16 inch shall be removed using a rotary file, wire brush, or by machining a skim cut not to exceed 1/8 inch on the outside diameter from the minimum diameter shown on the applicable detail drawing.

b. If cracks or severe pits are found, not exceeding 1/8 inch in depth for shafts up to and including 10 inches in diameter, or not exceeding 1/4 inch in depth, for shafts exceeding 10 inches in diameter, dress the ground areas to a large faired radius (three times the depth) to avoid stress concentration. Removal of pits and/or cracks by machining is permitted; however, in no case shall the outside diameter be less than 1/4 inch for shafts up to and including 10 inches in diameter, or less than 1/2 inch for shafts exceeding 10 inches in diameter from the minimum diameter shown on the shaft detail drawing. The ends of the machined area shall have a large radius to avoid stress concentration.

243-1.1.9.2 For Shaft Flanges. Minor pitting, not exceeding 1/16 inch in depth, shall be removed by using a fine abrasive material, rotary file, wire brush, or similar hand tool, provided that the integrity of the bolts and flange coupling are not adversely affected. Pits detected on the flange periphery may be removed by machining. The flange outside diameter shall not be reduced to an extent that would prevent the entire face of the bolts and nuts to contact the vertical face of the flange. Machining the mating vertical face of the flange to remove pits shall not result in reducing the flange thickness to less than 95 percent of the thickness as shown on the shaft detail drawing. Machining in the flange fillet area or the bolt or nut vertical face area is not permitted. For flanges on CPP shafting systems, all dowel holes, spigot fits, and O-ring seal contact areas shall be restored to conform with the shaft detail drawing.

243-1.1.9.3 For Shaft Tapers. Minor pitting on shaft taper surfaces may be removed with a fine abrasive material provided that the fit of the propeller or removable coupling on the shaft taper is not adversely affected. Cracks and/or severe pitting detected in the fit area in way of propellers and demountable couplings shall be repaired by welding. Note that weld repair to the propeller taper will require re-cold rolling of the taper in accordance with MIL-STD-2191. A 0.010 inch maximum skim cut may be taken on the propeller taper diameter, but in no case shall the length of the taper be extended more than .125 inch from the length shown on the shaft detail drawing. When repairs are accomplished to shaft tapers, an acceptable blue contact check with the applicable certified ring gage is required in accordance with the shaft detail drawing.

243-1.1.10 PLUGGING SHAFT ENDS. All shafting, except for CPP shafting systems, that is exposed to seawater and that has been bored throughout its length must have both ends properly plugged in order to prevent water from seeping into the hollow shaft and into the ship itself. On older ships, some shafts were tapped with a tapered pipe thread, and a thread sealant was applied to the threaded plug to ensure watertightness. Since the 1960s, new-design shafting has incorporated shaft ends that have been counterbored and the plug machined for a shrink fit. The plug is then cooled and allowed to expand tightly in the shaft bore. For the submarines that still have sand in the bore of the propeller shaft, compacting and locking plugs are installed at the aft end of the shaft to keep the sand compacted.

243-1.2 SHAFT COUPLINGS

243-1.2.1 FLANGE COUPLINGS. Integral flange couplings are commonly used for joining two sections of shafting. The two sections are held together by bolts and nuts on a common-pitch circle diameter. Most bolts and mating bolt holes are tapered; however, cylindrical fitted bolts are used in some applications. Tapered bolts are fitted to 90 percent minimum contact with the tapered bolt hole and are also fitted to leave a prescribed distance between the shaft flange face and mating face on the bolt head (refer to the applicable shaft detail drawing). The nuts are then tightened until the bolt head contacts the flange. When cylindrical bolts are used, they are tightened to the torque specified on the shaft detail drawing. Integral flange couplings for CPP shafting have O-rings installed between the flange faces to contain the actuating oil in the bore of the shaft.

243-1.2.2 OIL-PRESSURE-FITTED SHAFT COUPLINGS. Oil-pressure-fitted couplings made by SKF Industries, referred to as SKF or OK couplings, are used on some ships for joining sections of shafting. The couplings are generally used for joining inboard sections of shafting, but there are some applications on outboard sections as well. This type of coupling is designed to connect nontapered ends of shafts without using flanges, keyways, or bolts. They usually consist of a thin inner sleeve, tapered on its outside diameter, and a thicker outer sleeve, tapered on its inside diameter to match. The sleeves are positioned over the ends of the two shafts to be coupled, and oil is injected under pressure between the two sleeves to facilitate alignment and a compressive/friction fit over the shaft ends. Coupling removal and installation shall be in accordance with the applicable vendor or Navy technical manual. Special removal and installation equipment is required. Extreme care should be exercised during removal and installation due to the high oil pressures involved.

243-1.2.3 INBOARD COUPLINGS. For attaching the inboard sections of shafting to the outboard sections, another special design is sometimes used which consists of a removable split collar and a thick sleeve arranged to transmit ahead and astern torque and thrust. It is known as the inboard or removable flange coupling. This inboard coupling is fitted at the forward end of the stern tube shaft. When shaft removal is required, the inboard coupling is generally dismantled from the stern tube shaft and the shaft may then be withdrawn astern out of the ship. A good shrink fit is essential in the assembly of the coupling sleeve onto the shaft in order to provide for the transmission by friction of the imposed torque. As a backup to prevent shaft rotation in the event that the interference fit is lost, four keys, placed 90 degrees apart, are provided to transmit the torque between the shaft and the coupling sleeve. One key (and mating keyway) is 1/16 inch wider than the others to ensure correct orientation. The shrink fit for assembling the inboard coupling sleeve to the shaft is generally 0.001 inch per inch of the shaft diameter. See the applicable shaft detail drawing for specific requirements.

243-1.3 SHAFT JOURNALS AND SLEEVES

243-1.3.1 JOURNAL SURFACES. The inboard sections of shafting have raised journals in way of oil-lubricated bearings and bulkhead stuffing box seals. The outboard, or waterborne, sections of shafting have sleeves in way of waterborne bearings for steel shafting and raised lands for nonferrous shafting material. The sleeves used on steel shafting generally consist of bronze on older ships and copper-nickel alloy or NiCrMoCb (Inconel 625) alloy on newer ships. The sleeves are installed as either a one-piece sleeve shrunk onto the shaft, or a two-piece sleeve, split longitudinally (for shafts with flanges on both ends). Generally, the sleeves are installed to obtain a shrink fit of 0.00075 inch per inch of shaft diameter (see shaft detail drawing).

243-1.3.2 CARE OF LINE SHAFT JOURNALS. Journals should be maintained smooth and even at all times and kept free from rust and products of corrosion. To remove spots of rust, ridges, and sharp edges of scores, the journals should be lapped with an oil stone or with an oil stone powder. Carborundum may be used, but great care must be taken to remove all particles.

243-1.3.3 SLEEVE REPAIR IN WAY OF MAIN SEALS (For Non-Nuclear Submarines and Surface Ships Having Syntron-type Seals).

CAUTION

This procedure not applicable to shafts using Sealol-type seals.

Sleeves which have pitting and/or cracks exceeding 5/32-inch depth in way of the shaft sleeve should be replaced. Replacement of shaft seal sleeves which have pitting and/or cracks less than 5/32-inch deep is desirable providing time and material is available. However, as an alternate, pitting and cracks not exceeding 5/32-inch may be repaired by the application of a reinforced plastic insert in way of the syntron-type seals. The repair may be accomplished with the shaft in the ship, provided sufficient space is available, or with the shaft removed. Repair of sleeves without and with plastic inserts previously installed shall be in accordance with the following instructions.

243-1.3.3.1 Sleeves Without Inserts Previously Installed

1. Machine a concentric groove 0.1000 (-0.0000 +0.0625) inch deep and approximately 9 inches wide circumferentially around the shaft in way of the syntron seal. The ends of the groove shall be dovetailed (45 degrees). Using dial indicators, record runout readings on the machined area to assure that the groove is concentric to the sleeve.
2. After machining, perform a dye penetrant inspection of the machined area to assure complete removal of any cracks. The groove should be cleaned by sand blasting with black diamond dust and then with acetone. Precautions shall be taken to prevent dust damage to adjacent sleeve areas and equipment.
3. The following material will be required to install the epoxy insert:
   a Conap 1210 Resin and 08 hardener. Only acceptable source is:

      Conap Incorporate

      186 E. Union Street

      Allegheny, N Y.

   b Glass Tape-Construction shall be similar to that of cloth No. 164-150, Table VII of MIL-Y-1140E, Yard, Cord, Sleeving, Cloth and Tape Glass, except that tape shall have a Volan A finish (1-1/2″ width). Only known source is:

      Burlington Glass Fabric Co.

      1345 Avenue of Americas

      New York City, N.Y.

   c Philadelphia Resin Co. PR 225 mold release

   d Sheet metal dam (mold)-length to suit

   e Rubber tape as required

   f Two 40 KW rectifiers connected in parallel

   g 80 KW heating blanket

   h 0-250 degrees Fahrenheit thermometer
4. The epoxy insert is installed and machined in the following manner:
   a Preheat the glass tape in an atmosphere of dry air at 250 degrees Fahrenheit for 12 hours.

   b Prepare the resin formulation (measure carefully and mix thoroughly) according to the manufacturer's instructions. Resin temperature should be approximately 73 degrees Fahrenheit. Temperature of the shaft should be in the 65 to 80 degree Fahrenheit range (use 0 to 250 degrees Fahrenheit thermometer). The need for clean shaft surfaces and thorough mixing of the resin can not be overemphasized.

c Apply rubber tape to the existing sleeve adjacent to the undercut. Tape to be built in layers to a sufficient depth to act as a mold at each end of undercut to prevent runoff of epoxy.

d Apply the glass tape in the undercut, maintaining some tension so that the wrap is fairly tight (20 lbs ±10 lbs pull). Apply resin formulation as tape is wrapped around the shaft in such a way that resin is squeezed through the tape, sweeping the air out ahead of the resin and thoroughly wetting the tape. Wrap in successive layers of resin and tape until the outer diameter is approximately 0.100″ greater than the required finished machine size (i.e., design sleeve diameter plus 0.100″). There shall be a minimum of four plies of resin and glass tape wrap.

e Apply the mold release to the sheet metal dam and wrap it around the insert to prevent deformation during curing.

f Permit insert to cure tack-free at room temperature, rotating the shaft (if possible) during this time to prevent possible epoxy runoff. Approximately 24 hours is required. Remove sheet metal dam and rubber tape molding. A final post-cure between 150 to 200 degrees Fahrenheit is desirable for 8 to 10 hours. To accomplish post-cure, wrap 80 KW heating blankets on the sleeve forward and aft of the epoxy insert. Do not allow the blankets to touch the epoxy.

g Check the insert for proper hardness. Using a Barber-Coleman impressor, Model GY2J935, the minimum acceptable barcol hardness is 60. A minimal equivalent hardness of Rockwell M of 90 is satisfactory.

h Using the cutting tool, machine the epoxy insert concentric to the shaft sleeve. The finished diameter shall be machined to design with a tolerance of +0.010″, -0.000″.

i Perform a visual inspection of the epoxy insert, paying particular attention to the following:

(1) Translucence - Capability of light transmission not necessarily transparent or invisible; indicative of good wet out and thorough impregnation of the tape by the resin hardener formulation

(2) Presence of foreign matter in the finished epoxy insert (no foreign matter is acceptable)

(3) Smoothness (no sharp protrusions)

(4) No epoxy on bearing surfaces of bearing sleeves

j Using a high frequency, high voltage spark tester, test the epoxy insert for pinhole leaks. The spark tester shall be capable of producing a spark of approximately 10,000 volts, self-limited to a low current. The test shall be made by passing the spark electrode of the apparatus over, but not in contact with, the epoxy insert. Care shall be taken to keep the electrode in motion so as not to over-heat or burn the epoxy. A pinhole spark leak is evidenced by a bright spark which is distinct from the dull purple corona emanating from the sparking electrode when no pinholes are present. Correct any defects and reinspect in accordance with paragraphs 4h, 4i, and 4j.

k Final finish to surface of epoxy insert may be obtained by grinding or by polishing with No. 1 or No. 0 emery cloth. Measure to assure correct finished diameter. Using a dial indicator, measure runout readings on the finished insert to assure concentricity with the shaft sleeve.

l An inflatable boot, face type seals, and the refurbished stern tube stuffing box can now be reinstalled.

243-1.3.3.2 Sleeves With Inserts Previously Installed

1. If insert is unbonded, worn, or cracked, remove insert by machining or grinding. After insert removal, cracks or pits not exceeding 1/16 inch on dovetailed surface may be machined out by a 45 degree parallel dovetail cut down to the bottom of the groove. Cracks and pits extending no deeper than 0.1625 inch below the surface of the sleeve in the groove may be removed by grinding and fairing.

2. After grinding, perform a dye penetrant inspection of the area to assure complete removal of cracks. If any cracks are detected deeper than 0.1625 inch, the sleeve shall be replaced. If cracks are not detected, proceed

with cleaning the groove. The groove should be cleaned by sand blasting with black diamond dust and then with acetone. Precautions shall be taken to prevent dust damage to adjacent sleeve areas and equipment.

3. The following material will be required to install the epoxy insert:
   a Conap 1210 Resin and 08 hardener. Only acceptable source is:

      Conap Incorporated

      186 E. Union Street

      Allegheny, N.Y.

   b Glass Tape - Construction shall be similar to that of cloth No. 164-150, Table VII of MIL-Y-1140E, Yard, Cord, Sleeving, Cloth and Tape Glass, except that tape shall have a Volan A finish (1-1/2″ width). Only known source is:

      Burlington Glass Fabric Co.

      1345 Avenue of Americas

      New York City, N.Y.

   c Philadelphia Resin Co. PR 225 mold release
   d Sheet metal dam (mold) length to suit
   e Rubber tape as required
   f Two 40 KW rectifiers connected in parallel
   g 80 KW heating blanket
   h 0-250 degrees Fahrenheit thermometer

4. The epoxy insert is installed and machined in the following manner:
   a Preheat the glass tape in an atmosphere of dry air at 250 degrees Fahrenheit for 12 hours.
   b Prepare the resin formulation (measure carefully and mix thoroughly) according to the manufacturer's instructions. Resin temperature should be approximately 73 degrees Fahrenheit. Temperature of the shaft should be in the 65 to 80 degrees Fahrenheit range (use 0 to 250 degrees Fahrenheit thermometer). The need for clean shaft surfaces and thorough mixing of the resin can not be overemphasized.
   c Apply rubber tape to the existing sleeve adjacent to the undercut. Tape to be built in layers to a sufficient depth to act as a mold at each end of undercut to prevent runoff of epoxy.
   d Apply the glass tape in the undercut, maintaining some tension so that the wrap is fairly tight (20 lbs ±10 lbs pull). Apply resin formulation as tape is wrapped around the shaft in such a way that resin is squeezed through the tape, sweeping the air out ahead of the resin and thoroughly wetting the tape. Wrap in successive layers of resin and tape until the outer diameter is approximately 0.100″ greater than the required finished machine size (i.e., design sleeve diameter plus 0.100″). There shall be a minimum of four plies of resin and glass tape wrap.
   e Apply the mold release to the sheet metal dam and wrap it around the insert to prevent deformation during curing.
   f Permit insert to cure tack-free at room temperature, rotating the shaft (if possible) during this time to prevent possible epoxy runoff. Approximately 24 hours is required. Remove sheet metal dam and rubber tape molding. A final post-cure between 150 and 200 degrees Fahrenheit is desirable for 8 to 10 hours. To accomplish post-cure, wrap 80 KW heating blankets on the sleeve forward and aft of the epoxy insert. Do not allow the blankets to touch the epoxy.
   g Check the insert for proper hardness. Using a Barber-Coleman impressor, model GYZJ935, the minimum acceptable barcol hardness is 60. A minimal equivalent hardness of Rockwell M of 90 is satisfactory.
   h Using the cutting tool, machine the epoxy insert concentric to the shaft sleeve. The finished diameter shall be machined to design with a tolerance of +0.010″, -0.000″.

i Perform a visual inspection of the epoxy insert, paying particular attention to the following:

(1) Translucence - Capability of light transmission not necessarily transparent or invisible; indicative of good wet out and thorough impregnation of the tape by the resin hardener formulation

(2) Presence of foreign matter in the finished epoxy insert (no foreign matter is acceptable)

(3) Smoothness (no sharp protrusions)

(4) No epoxy on bearing surfaces of bearing sleeves

j Using a high frequency, high voltage spark tester, test the epoxy insert for pinhole leaks. The spark tester shall be capable of producing a spark of approximately 10,000 volts, self-limited to a low current. The test shall be made by passing the spark electrode of the apparatus over, but not in contact with, the epoxy insert. Care shall be taken to keep the electrode in motion so as not to over-heat or burn the epoxy. A pinhole spark leak is evidenced by a bright spark which is distinct from the dull purple corona emanating from the sparking electrode when no pinholes are present. Correct any defects and reinspect in accordance with paragraphs 4h, 4i, and 4j.

k Final finish to surface of epoxy insert may be obtained by grinding or by polishing with No. 1 or No. 0 emery cloth. Measure to assure correct finished diameter. Using a dial indicator, measure runout readings on the finished insert to assure concentricity with the shaft sleeve.

l An inflatable boot, face type seals, and the refurbished stern tube stuffing box can now be reinstalled.

243-1.3.4 IN-SHOP REPAIR OF SHAFT SLEEVES IN WAY OF WATERBORNE BEARINGS. The criteria in paragraphs 243-1.3.4.1 through 243-1.3.4.7 apply to those sleeves that do not require removal to repair the shaft and are or sufficient length to accommodate and extend beyond the bearing or fairwater a minimum of one inch. Otherwise, replace the sleeve. On FPP shafting, under no circumstances should the last two inches of the aftermost sleeve be reduced in outside diameter. Note in the applicable docking report all sleeve work that involves increasing the bearing clearances or installing oversize staves.

243-1.3.4.1 If waterborne bearing sleeves are worn, pitted, otherwise damaged and rough to a depth less than or equal to 0.030 inch from the original design size, the roughness may be hand-smoothed or removed by making a skim cut on a lathe. Standard-thickness bearing staves may be installed, even though the bearing clearance so obtained is up to 0.060 inch greater than the original design clearance. Providing slightly more initial clearance is therefore more desirable than removing metal from the sleeve to accommodate oversize-thickness staves.

243-1.3.4.2 If waterborne bearing sleeves are worn, pitted, or otherwise damaged and rough to a depth greater than 0.030 inch, but less than or equal to 0.062 inch from original design size, set up the shaft in a lathe and skim-cut the sleeve to refinish the journal surface. The new journal diameter shall be 0.125 inch less than the original design diameter. When the shaft journal has been modified, install 1/16-inch oversize-thickness bearing staves in the upper and lower halves of the bearing bushing to restore the bearing to the original design clearance.

NOTE

Oversize-thickness staves are oversize only in the thickness dimension. The width of the backing material is the same as for standard-size staves. Oversize-thickness staves will therefore fit in the bushing slots from which standard staves have been removed. Do not use shims in back of standard-thickness staves. The Navy supply system has a stock of 1/16- and 1/8-inch oversize-thickness staves of common sizes and lengths.

243-1.3.4.3 If waterborne bearing sleeves are worn, pitted, or otherwise damaged and rough to a depth greater than 0.062 inch but less than or equal to 0.092 inch from original design size, set up the shaft in a lathe and skim-cut the sleeve to refinish the journal surface. With the journal surface thus renewed, install 1/16-inch oversize-thickness staves in the bearing bushing, even though the bearing clearance so obtained is up to 0.060 inch greater than the original design clearance.

243-1.3.4.4 If waterborne bearing sleeves are worn, pitted, or otherwise damaged to a depth greater than 0.092 inch but less than or equal to 0.125 inch from original design size, set up the shaft in a lathe and skim-cut the sleeve to refinish the journal surface. The new journal diameter shall be 0.250 inch less than the original design diameter. Install 1/8-inch oversize thickness staves.

243-1.3.4.5 If waterborne bearing sleeves are worn, pitted, or otherwise damaged and rough to a depth greater than 0.125 inch but less than or equal to 0.155 inch from the original design size, set up the shaft in a lathe and skim-cut the sleeve to refinish the journal surface. With the journal surface thus renewed, install 1/8-inch oversize-thickness staves in the bearing bushing, even though the bearing clearance so obtained is up to 0.060 inch greater than the original design clearance.

243-1.3.4.6 If waterborne bearing sleeves are worn, pitted, or otherwise damaged and rough to a depth greater than 0.155 inch from the original design size, replace the sleeves.

NOTE

An alternate procedure from that listed in 243-1.3.4.1 to 243-1.3.4.6 is as follows:

NOTE

If the waterborne bearing sleeves are worn, pitted, or otherwise damaged and rough to a depth less than or equal to 0.155 inch from the original design size, set up the shaft in a lathe and skim-cut the sleeve by the minimum amount necessary to restore and refinish the journal surface to the design surface requirement. Determine the appropriate stave thickness necessary to achieve the design bearing clearance in accordance with the standard drawing for water-lubricated stern tube and strut bearings, NAVSHIPS dwg 803-1385664. The new non-standard thickness staves can be ordered directly from the manufacturer.

NOTE

In no case shall the sleeve thickness be reduced to less than 75 percent of its design thickness.

243-1.3.4.7 When it is considered expedient to use oversize thickness staves, the repair facility should consider the general condition of the shafting, its covering, the sleeves, the potential service life, and the relative economy of resleeving the shaft as compared with reconditioning the journals and installing oversize staves. Remember that a reduction of sleeve diameter due to wear is usually nonuniform and will probably vary from the center of the bearing to the ends. Use oversize thickness staves, therefore, to compensate for sleeve wear, but only when the sleeve has been turned in a lathe to a new uniform diameter. When shaft sleeves are reduced in diameter by turning in a lathe, it is important to observe the following precautions:

a. Do not reduce the diameter of a sleeve in way of the stern tube seal.

b. Do not destroy the bonding joint between the various sleeves and the rubber or plastic covering.

c. For FPP shafting. On the sleeve adjacent to the propeller taper, do not cut away the original sleeve surface for approximately two inches at the aftermost end. This is the seating surface for the packing gland that maintains a watertight seal between the propeller and shaft sleeve.

d. For sleeves in way of packing box seals, either maintain the original diameter in way of the stern tube packing gland or compensate with oversize packing.

e. Do not use plastic or rubber, or spray metal deposits to build up shaft sleeves in way of packing boxes.

243-1.4 SHAFT KEYS

243-1.4.1 PROPELLER SHAFT KEYS AND KEYWAYS. An FPP shafting system has two keys installed in the propeller shaft as a backup to the interference fit of the propeller hub on the shaft. Although the keys are considered a backup system, they are designed with sufficient strength to carry the design torque. The keyways have rounded corner fillets, and the keys have chamfered corners. The keyway forward ends are also rounded (spooned out) to reduce stress concentrations. The keys are fitted to the shaft to provide a light drive fit. A dowel pin keeps the keys from sliding when installing the propeller. One key (and mating keyway) is 1/16 inch wider than the other to ensure correct orientation. When the shaft is in the drydock position, the smaller propeller key and keyway are at the top. The larger propeller key is in the same circumferential orientation as the larger inboard coupling key.

243-1.5 ALINEMENT OF SHAFTING AND BEARINGS

243-1.5.1 GENERAL DISCUSSION OF ALINEMENT OF SHAFTING AND BEARINGS. The alinement of the shafting and bearings is not permanently fixed but changes with every docking, due to changes in the keel blocking, and for the same docking, the alinement changes with temperature variations. Alinement is even dependent upon the direction of the sun's rays relative to the fore-and- aft line of the ship. The alinement of the struts and stern tubes in relation to one another, as well as their alinement with the main propelling machinery, will undergo a natural change if the propeller, propeller shaft, line shaft, bearing, or all of these parts are temporarily removed. The alinement of shafting and bearings is affected by the temporary removal of machinery attached thereto, or in the vicinity thereof, because of the redistribution of weight and stresses. Furthermore, alinement is not the same when the vessel is waterborne as when it is in drydock. Alinement differs when the ship rides in the hollow or on the crest of a wave and it also varies with different conditions of loading of the ship. In the case of destroyers, some of these departures from true alinement are very marked and may vary in different types of destroyers. With larger hulls, as in aircraft carriers, etc., there will exist a tendency toward misalinement under the conditions cited above, although it may not be so sensitive in its effect so as to cause an objectionable operating condition. The final alinement of the main propulsion shafting of a vessel should always be accomplished when the vessel is waterborne.

243-1.5.2 IMPORTANCE OF CORRECT ALINEMENT. Maintaining proper shafting system alinement is essential to ship operation and mission. Specifically, proper alinement:

a. Prevents excessive shaft vibration due to a lightly or unloaded bearing(s).

b. Prevents excessive internal misalinement of reduction gear (bull gear) elements which can cause destructive tooth wear (pitting) or tooth failure.

c. Prevents overload of system bearings which can lead to premature bearing wear or failure.

d. Prevents shaft failure due to excessive bending stresses.

243-1.5.3 WHEN TO CHECK ALINEMENT. Baseline propulsion shafting system alinement data and historical alinement trends for each individual ship are being established and maintained by FTSCLANT (formerly NAVSEACENLANT) and FTSCPAC (formerly NAVSEACENPAC). Since individual ship alinement conditions are unique, an engineering evaluation of the need for checking shafting system alinement shall be conducted by a responsible Navy Engineering Organization (such as a Naval Shipyard, SUPSHIP, or FTSC) to determine the minimum work necessary. In general, this engineering evaluation shall include participation by FTSCLANT or FTSCPAC and should be scheduled prior to each drydock availability. Propulsion shafting system alinement for surface ships and submarines shall be checked under the following conditions:

a. When ship operation is such that misalinement is suspected; e.g., repeated system bearing failures, a ship grounding, reduction gear elements showing abnormal tooth contacts, unexplained shafting system vibration, etc.

b. During each drydock availability (or other availability) when work is or will be performed that may affect shaft alinement, e.g., significant welding or other structural work in the general vicinity of the propulsion plant, etc.

c. (For submarines) In addition to the above conditions, when propulsion shafting is routinely removed or waterborne bearings are restaved. Note that this is a periodicity-based requirement, intended for regularly scheduled changeouts only.

NOTE

The shaft alinement checks discussed above refer to the general practice of measuring bearing loads on the inboard sections of shafting and the bull gear, usually the most critical area of shafting system alinement. However, waterborne (outboard) shaft/bearing alinement shall also be checked (by the optical method - see paragraph 243-1.5.6) if misalinement of the waterborne shafting is suspected, such as from observed uneven wear of waterborne bearings. When alinement checks of waterborne shafting are performed, they shall be performed in conjunction with inboard shafting alinement checks and a complete system alinement analysis shall be accomplished.

243-1.5.4 EXTENT OF ALINEMENT CHECKS. Complete shafting system alinement checks shall consist of measuring loads on all inboard bearings, including both bull gear bearings (or at least one bull gear bearing if time does not permit both). However, the number of bearings required for measurement may be reduced, in particular for long shafting systems with multiple inboard bearings (CVNs, LHDs, etc.), if the engineering evaluation determines that a complete shaft alinement check is unnecessary. If a flexible coupling exists between the reduction gear and the first line shaft bearing outside of the gear, measurement of bull gear bearing loads is not required.

243-1.5.4.1 For Surface Ships. If the engineering evaluation supports the need for shafting system alinement checks, the final alinement check shall be taken with the ship waterborne at the end of the availability (or after all work that may affect shaft alinement is completed). Earlier checks prior to and/or during drydocking may prove advantageous by minimizing the extent of realinement required at the end of the availability.

243-1.5.4.2 For Submarines. If the engineering evaluation supports the need for a complete alinement check, perform four sets: during preavailability-waterborne (just prior to drydocking), preavailability-drydock (just after drydocking), postavailability-drydock (after all work affecting alinement is completed), and postavailability-waterborne. However, in cases where there are no known shafting-related problems and the work affecting the shafting system alinement is limited to removal of shafting or restaving of waterborne bearings, preavailability-drydock and postavailability-drydock alinement checks are not required.

NOTE

> For surface ships and submarines, always perform final shafting alinement checks with the ship waterborne under normal draft and load conditions, if possible. Also, when coming out of drydock, the ship's hull should be given time to stabilize in the water (up to two days, if practical) prior to performing the final alinement checks. Final alinement checks may be performed up to 90 days after completion of the availability.

243-1.5.5 METHODS FOR CHECKING SHAFT ALINEMENT. Historically, various methods have been successfully utilized for measuring shafting system alinement. The method chosen will often be dictated by specific ship class requirements based on shafting system arrangement. The following are the most common methods currently in use.

243-1.5.5.1 Hydraulic Jack Method. This is generally the most widely used and accurate method for checking shaft alinement. It provides a direct means of measuring inboard bearing loads (including bull gear bearings) and involves placing a hydraulic jack and calibrated load cell under the shaft near the bearing and a dial indicator on top of the shaft for use in measuring and plotting load versus lift. Detailed instructions for the use of the hydraulic jack method for shaft alinement measurement and analysis are contained in NAVSEA Handbook S6420-AC-HBK-010, Volume 1, Bearings, Measurement of Load, dated 1 October 1986.

243-1.5.5.2 Strain Gage Method. The strain gage method represents the latest technology for measuring shafting alinement and is becoming more widely utilized as procedures are developed for various ship classes. This method uses strain gages installed at predetermined locations along the inboard shafting to measure shaft bending strains. These strains are then mathematically converted to shaft bearing loads. Although the strain gage method cannot be used to determine shaft journal runout (as the hydraulic jack method can), it does offer the following benefits:

a. Bull gear and thrust journal bearing loads can usually be measured without any disassembling of these components.

b. Once the strain gages are in place, repetitive alinement checks during a ship's availability are quick and easy.

c. Horizontal (athwartship) bearing loads can be measured to assess athwartship shaft alinement.

d. The strain gage method, unlike the hydraulic jack method, is readily adaptable for use on ships which have resiliently (″soft″) mounted reduction gears, such as those installed on DD 963, CG 47, and DDG 51 class ships.

NOTE

FTSCLANT, FTSCPAC, and NAVSURFWARCEN SHIPSYSENGSTA, PHILA (formerly NAVSSES) have developed and validated strain gage procedures for various ship classes and, upon request, will perform shaft alinement measurements using this method. Otherwise, the strain gage method shall only be used with NAVSURFWARCEN SHIPSYSENGSTA, PHILA approved procedures and by personnel with specialized training by NAVSURWARCEN SHIPSYSENGSTA, PHILA in this technology.

NOTE

For ships with resiliently (″soft″) mounted reduction gears (DD 963, DD 993, CG 47, and DDG 51 classes), the strain gage method is the only acceptable method for measuring shafting system alinement. Contact FTSCLANT, or FTSCPAC.

243-1.5.5.3 Gap and Sag (Offset) Method. This method involves measuring differences in the slope and vertical position of one shaft flange relative to its mating flange when the flanged joint is disassembled. The measurements are then compared to calculated values for proper alinement. Gap and sag was the common method for checking shaft alinement prior to the introduction of the more versatile and accurate hydraulic jack method. Its use today is limited to some ships with unusual or restrictive shafting system arrangements and to quick intermediate alinement checks during ship construction.

243-1.5.6 OPTICAL METHOD OF ALINING SHAFTING. The optical alinement method (boresighting) is used mostly for waterborne bearing alinement checks. It can also be used to determine the preliminary location of inboard bearings when all the shafting has been removed. This method requires a small telescope (borescope with a cross hair lens) attached (alined) to the axis of rotation of a bull gear or line shaft flange. This method makes use of line-of-sight relationship of bearing bores to the axis of rotation of the shaft. To obtain meaningful results, shaft sag must be accounted for. Optical work must be accomplished at night, preferably between midnight and dawn, when the ship's hull is least affected by temperature variations from the sun's radiation.

243-1.5.7 PROCEDURE FOR CHECKING AND ASSESSING SHAFT ALINEMENT. When a check and assessment of a ship's shafting alinement is planned, the repair activity shall comply with the following procedure:

1. Contact FTSCLANT (Code 4312) or FTSCPAC (Code 302) prior to the alinement checks to ensure or obtain the latest design data and procedures.
2. After alinement checks are completed, the measured data shall be evaluated and a complete assessment made as to the acceptability of the alinement. The assessment shall account for, as applicable, the various factors affecting alinement (thermal growth, waterborne bearing wear, ship loading, etc.) as well as the limiting design parameters (maximum and minimum bearing loads, allowable bull gear bearing load differential, maximum allowable waterborne bearing wear, flexible coupling alinement, etc.). Upon request, FTSCLANT or FTSCPAC can assist with this evaluation.

3. Present alinement assessment with recommendations to FTSCLANT or FTSCPAC for review. This review is required prior to any shaft realinement work.
4. Submit final alinement data package to FTSCLANT or FTSCPAC for information and incorporation into their alinement data bank.

NOTE

Training classes in the various methods for checking and assessing shaft alinement are held regularly at FTSCLANT or FTSCPAC. Contact these organizations for more information.

243-1.6 PROPELLER REMOVAL AND INSTALLATION

243-1.6.1 WATERBORNE PROPELLER REMOVAL AND INSTALLATION. Waterborne propeller removal and installation for taper-mounted (MONOBLOC and build-up) propellers shall be in accordance with NAVSEA S0600-AA-PRO-030, **Underwater Ship Husbandry Manual, Chapter 3, Propellers** .

243-1.6.2 DRYDOCK PROPELLER REMOVAL AND INSTALLATION. Drydock propeller removal and installation for taper-mounted (MONOBLOC and build-up) propellers shall be in general accordance with S0600-AA-PRO-030, Underwater Ship Husbandry Manual, Chapter 3, Propellers, as modified by S9086-HP-STM-010/CH-245, NSTM Chapter 245, Propellers, Change 4, dated 15 August 1988 for applicability to a drydock verses waterborne situation. These modifications for drydock applicability most notably include:

a. Removal of propellers by explosives is prohibited in drydock.

b. Requirements for the use of propeller blade edge guards, type of preservative for filling voids in propeller hub and cap, staking of propeller nut locking and balancing key retaining screws, propeller removal if the propeller had been last installed while waterborne, and drydock inspection forms (if propeller removed had been last installed while waterborne) shall be in accordance with S9086-HP-STM-010/CH-245, NSTM Chapter 245, Propellers, Change 4, dated 15 August 1988.

c. The requirement for shaft-to-propeller taper blue contact check shall be in accordance with S9086-HP-STM-010/CH-245, NSTM Chapter 245, Propellers, Change 4, dated 15 August 1988 except that a blue contact check of the propeller hub bore to shaft taper is not required if all of the following conditions exist:
   1 The propeller to be installed is the one which had been last removed from the shaft.
   2 The previous propeller installation had not been accomplished waterborne.
   3 No propeller or shaft work was accomplished during the drydocking that could affect the propeller-to-shaft taper fit.

243-1.6.3 CONTROLLABLE PITCH PROPELLER HUB REMOVAL AND INSTALLATION. Instructions for removal and installation of controllable pitch propeller hubs are found in the applicable technical manuals.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.